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Hybrid approach to medical decision-making: prediction of heart disease with artificial neural network

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ABSTRACT

Heart disease prediction is important in today's world because it helps to reduce the unpredictable death rate of patients, and cardiac diseases are considered one of the most serious diseases affecting people. Hence, in this paper, a heart disease prediction model is designed for effective prediction of heart diseases by means of machine learning (ML) and deep learning (DL). This prediction uses the proposed method of an artificial neutral network and the Chi2 feature selection method applied to determine which features from the dataset were suitable for prediction. The proposed methodology uses classifiers like support vector machines (SVM), Naive Bayes (NB), logistic regression (LR), random forest (RF), and artificial neural networks (ANN). Python was used to conduct the study that assessed the ANN system proposal with the Cleveland heart disease dataset at the University of California (UCI). Compared to other algorithms, the model achieves an accuracy of 97.64% and takes 0.49 seconds to execute, making it superior in predicting heart disease.

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1. INTRODUCTION

The human heart is the most important portion of the human body because it is responsible for pumping oxygen-rich blood to the rest of the body through a network of veins and arteries. The human heart is the most important part of the human body. The term heart disease refers to a category of conditions that might harm our hearts [1], [2]. Heart disease [3] is a state that affects the heart. and it is suffered from different kinds of diseases in the heart with many or few blood discharges [4]. At an earlier period of 10 years, this heart disease is deemed a deadly disease [5], which is one of the foremost reasons for death in the world [6]. Since the coronary arteries are contracted, the flow of blood to the heart will automatically get slow or cease, by means of causing the heart attack or chest pain [7], [8]. In various countries plus India, heart disease is considered as the major cause of casualties, which slay one person at every 34 seconds in the United States [9]. In India, based on the report of Indian Heart Association, the people at less than 50 years of age and under 40 years of age are affected with heart disease at the percentage of 50 and 25. Most of the urban people are affected by heart diseases nearly 3 times as the rural population. The prediction of this heart disease can be examined with different symptoms like blood pressure breathing problems, shortness of breath, excess alcohol consumption, smoking, age factor, maintaining a state of constant tension, excessive phlegm, excess nausea, weakness of physical body, heredity excess body fat, hurt burn, and stomach pain high blood pressure, inequity in digestive purposes, pain in the arms, dizzy sensations, chest irritation, chest pain, deep sweating while lacking of physical activity, extending with discomfort due to artery lump in the heart and swollen feet and fatigue [1], [3], [4], [10], [11]. Some symptoms are linked with heart disease, which is hard to diagnose earlier and superior. The databases of heart disease patients can be related to real-life applications. Still, it is challenging to spot heart sickness because of some contributing risk factors like high cholesterol, abnormal pulse rate, high blood pressure, diabetes, and various other factors [3]. Thus, the treatment and analysis of heart disease are very complicated.

2. METHOD

Consider Figure 1, this research aims to develop a reliable method for predicting heart disease, specifically coronary arterial disease or coronary heart disease, with the greatest accuracy possible. The steps that must be taken are summarised as follows:

a. An optimized feature selection approach for identifying cardiovascular diseases (CVD) using a machine learning (ML) approach;
b. Girst approach where balance dataset methodologies had applied on an imbalanced dataset to give more accurate and unbiased results; and
c. On this balance dataset, Hybrid feature selection technique chi-square method with optimization algorithms was used to improve CVD detection and prediction accuracy at an early stage by artificial neural networks (ANN) classification methodologies.

The different models are judged on how well they did overall when they were tested with different classification models for different features. This is how it worked: The best model, an ANN learning model, was used for the final deployment for predicting CVD accurately.

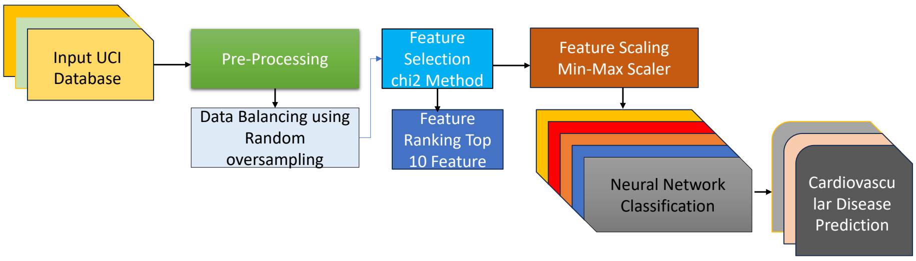

Figure 1. Proposed method

In the proposed systems during the pre-processing step, features are selected, feature scaling is conducted, and class balance is carried out, a Chi2 is the best feature selection technique used to choose the best features for the prediction. There are 164 examples in the dataset that belong to class 0, and 139 instances that belong to class 1 in the dataset. Class balance is accomplished by the use of random oversampling and under sampling methods [12]. Naive Bayes (NB), support vector machines (SVM), logistic regression (LR), random forest (RF), AdaBoost classifier, stockist gradient descent (SGD), K-nearest neighbor (KNN), and an ANN are utilized in the classification process for certain characteristics that have been chosen. The final step of the classification process involves determining whether or not a person has heart disease. ML requires feature selection strategies to obtain the best properties for categorization. This also speeds up the process. In this proposed paper chose the Chi2 feature selection method. In statistics, chi-square tests two occurrences independence. We get the observed count O and the anticipated count E from two variables. The chi-square quantifies the deviation between predicted and observed counts.

$$x_c^2 = \sum \frac{(o_i - E_i)^2}{E_i} \tag{1}$$

Where C is degrees of freedom, O is observed value(s), E is expected value(s). There are two basic ways of randomly resampling an unbalanced dataset, one termed under-sampling and the other called oversampling. In this study, the dataset we are dealing with is skewed. There are a total of 303 datasets accessible, of which 165 pertain to heart defects and 138 to healthy hearts.

2.1. Performance parameters

A scale that included accuracy, sensitivity, specificity, precision, and recall was used to measure how well classifiers worked [13], [14]. False negatives are possible, but only if the algorithm correctly predicts that the patient is suffering from heart disease.

- Accuracy: the system can create accurate predictions that are measured by the accuracy of its performance.

$$Accuracy = \left(\frac{CorrectPrediction}{Total\ Prediction}\right) \times 100 \quad (2)$$

- Sensitivity: system sensitivity is a performance statistic that assesses a system's capacity to accurately forecast favourable outcomes.

$$Sensitivity = \left(\frac{True\ Positive}{(True\ Positive + False\ Negative)}\right) \times 100 \quad (3)$$

- Specificity: performance parameter specificity assesses the system's ability to correctly forecast negative outcomes.

$$Specificity = \left(\frac{True\ Negative}{(True\ Negative + False\ Positive\ )}\right) \times 100 \quad (4)$$

- Precision: precision refers to a system's ability to produce just the most relevant data.

$$Precision = \left(\frac{True\ Positive}{(True\ Positive + False\ Positive\ )}\right) \times 100 \quad (5)$$

- F-Measure: F-Measure utilises the harmonic mean to combine accuracy and sensitivity measurements.

$$F - Measure = 2 \times \left(\frac{Sensitivity * Precision}{Sensitivity + Precision}\right) \times 100 \quad (6)$$

3. RESULTS AND DISCUSSION

Patients with heart disease were classified using ML [15]–[20] NB, SVM [21], LR [22], RF, Adaboost, and ANN [23]. The experiments used data from UCI's Cleveland dataset [24]–[26]. The dataset identified heart disease using several medical parameters. These variables were used to categorise, with class 1 being sick and class 0 being disease-free. Consider Table 1, Table 2 using these attributes, system performance parameters like precision, sensitivity, specificity, and accuracy were utilized.

Table 1. (Dataset-1)

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
LR	83.61	86.76	93.56	89.01
NB	82.25	80.78	85.90	82.89
SVM	81.97	81.66	91.76	85.56
KNN	65.57	55.45	57.46	56.23
RF	81.97	75.67	84.12	80.56
XGBoost	73.77	78.76	84.90	81.32
SGD	63.93	89.12	46.09	63.56
ANN	72.73	79.67	83.56	80.89

Table 2. (Dataset-2)

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
LR	84.00	90.07	80.07	85.01
NB	85.25	80.07	84.07	82.08
SVM	79.00	84.07	77.05	81.07
KNN	64.00	70.07	66.07	68.07
RF	82.00	85.07	83.10	84.07
XGBoost	82.00	88.07	80.57	84.18
SGD	61.00	61.07	89.03	72.11
ANN	95.63	89.07	81	82.09

Initially, all characteristics of the dataset were tested without any sort of pre-processing, data load balancing, or feature selection applied to them. Classifier performance on the whole feature set is shown in Tables 1 and 2. The best overall performance was achieved by the NB classifier, while the SGD classifier achieved the worst overall performance. The graphs in Figure 2 are taken from Tables 1 and 2, which illustrate the details of the performance matrix process for both combined datasets.

According to Figure 3, the findings, scaling has a significant and favourable effect on the performance of ANN, RF, and NB classifiers, but it does not have this effect on the performance of SVM, XGBoost, or SGD classifiers. Table 2 demonstrates the influence that scaling, random oversampling (class balancing), and feature selection approaches have on the performance of classifiers.

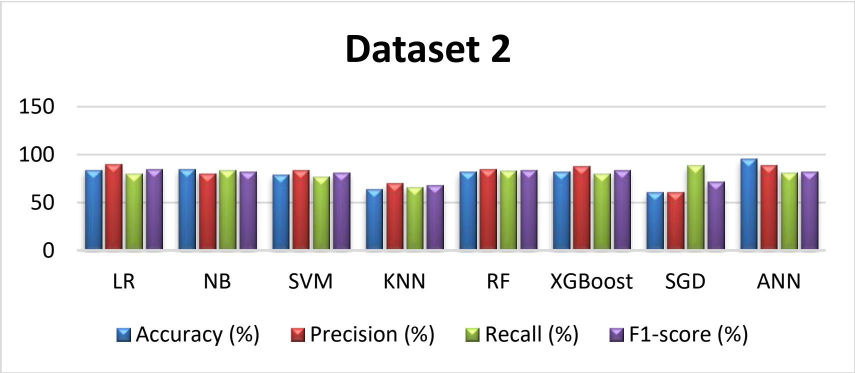

Figure 2. Performance comparison after random oversampling and feature selection

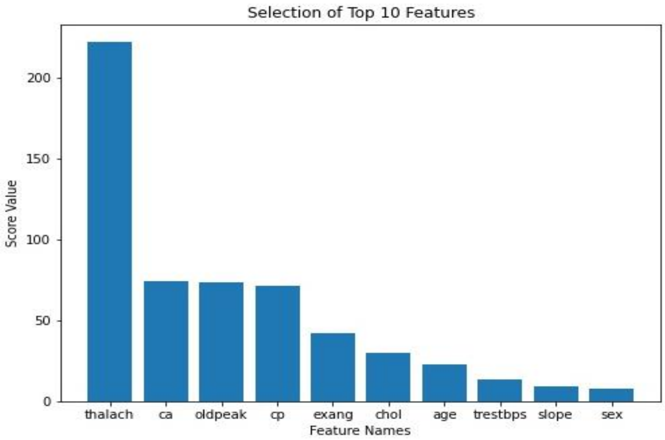

Figure 3. Top 10 K best selected features

We further applied the feature selection technique using the Chi2 algorithm, which is the best selection algorithm. We used the Chi2 is best selection algorithm to select the top ten features. The SVM accuracy is increased by 2.03%, and the accuracy of the LR is increased by 0.44%. The accuracy of NB had changed from 82.25% to 85.25%, an increase of 3.00%, whereas KNN and RF algorithms had shown a decline in accuracy after random undersampling.

The impact of scaling, random oversampling (class balance), and feature selection technique on the performance of classifiers is shown in Table 3, and Figure 4. The ultimate model that we had applied, i.e., ANN, had shown an increase in accuracy from 72.73% to 96.74%. Results indicate that scaling, class balancing using random undersampling, and feature selection positively impact the ANN algorithm. Using this mechanism, we had achieved the highest level of accuracy.

Table 3. Performance of model after random under sampling (dataset-1)

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
LR	84.00	83	77	80
NB	85.25	80	84	82
SVM	84.00	84	89	76
KNN	61.00	66	66	66
RF	79.00	82	80	81
XGBoost	79.00	81	83	82
SGD	59.00	51	96	67
ANN	**96.74**	**89**	**90**	**89**

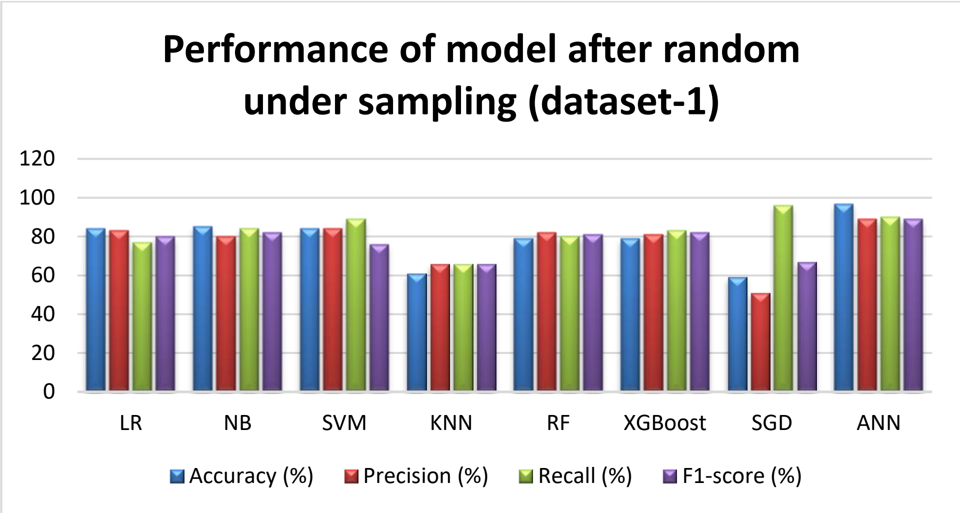

Figure 4. Performance analysis after feature selection and random under sampling

The time it takes to predict CVD detection is shown in Table 4. It is observed that feature selection with Chi2 methodologies, through which we selected only the top 10 features, reduced the time for performing the model. We had achieved a reduction of 0.49 seconds in terms of our best-performing ANN algorithm, followed by a 0.22 second reduction in the RF classification algorithm.

Table 4. Time taken by model before and after feature selection (dataset-1)

Model	Full features (sec)	Top 10 features (sec)	Reduction in time (sec)
Logistics regression	1.79	1.62	0.17
NB	1.88	1.82	0.06
SVM	2.12	2.01	0.11
K-NN	2.33	2.17	0.16
SGD	1.89	1.81	0.08
RF	2.00	1.78	0.22
XGBoost	2.16	2.05	0.11
ANN	2.46	1.97	0.49

In Table 5 and Figure 5, the best ten features from the provided dataset were chosen for this feature selection process. In the case of ANN, the performance increased from 72.73% to 96.74% in XGBoost, the performance increased from 73.7 to 81.97ormance increased from 72.73% to 96.74% in XGBoost, the performance increased from 73.7 to 81.97% and in the case of RF, it increased from 81.97% to 85.25%. NB, SVM accuracy dropped from 82.25% to 67.21% and from 81.97% to 77.05%. In the case of LR, the accuracy performance decreased from 83.61 to 80.33.

Table 5. Accuracy analysis before and after (dataset-1)

Sr. No	Classifiers	Without data balancing and feature selection (all features) (%)	Data balancing feature selection and feature scaling (oversampling) top 10 features (%)	Data balancing feature selection and feature scaling (under sampling) top 10 features (%)
1	LR	83.61	78.63	80.33
2	NB	82.25	42.62	67.21
3	SVM	81.97	78.69	77.05
4	KNN	65.57	59.02	62.30
5	SGD	63.93	42.62	67.21
6	RF	81.97	80.33	85.25
7	XGBoost	73.70	80.34	81.97
8	ANN	72.73	95.63	96.74

The execution time it takes to predict CVD detection is shown in Tables 5 to 7 and Figure 6, This is reflected in the improvement in the classification performance analysis. Even the time required to train and test the model had been reduced from 2.46 to 1.97, thus reducing the time by 0.49 seconds, which is good for the early prediction of heart disease.

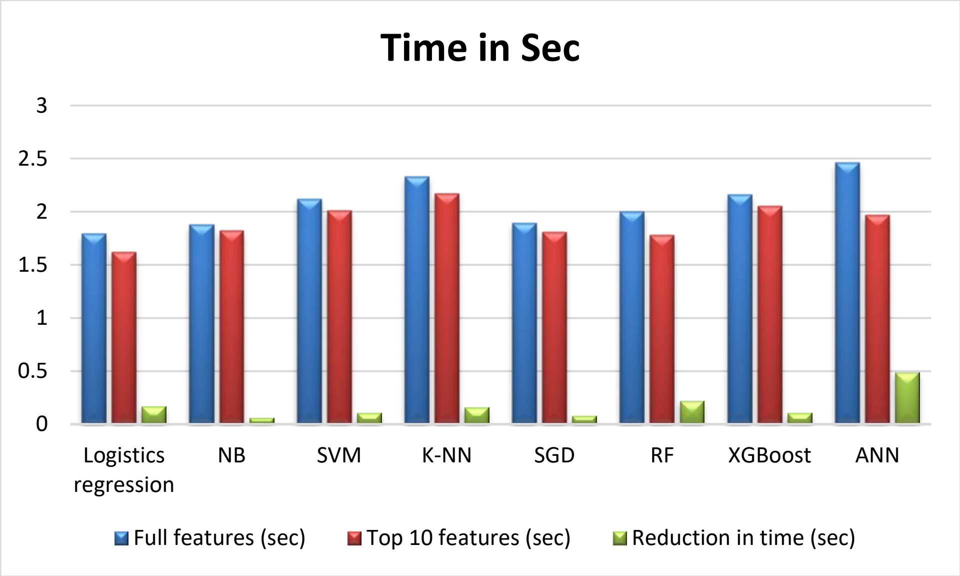

Figure 5. Time taken by model before and after feature selection

Table 6. Analysis using the dataset-2

Sr. No	ML model	All dataset (%)	Feature selection (ANOVA test) (%)	Random over sampling	Feature selection (ANOVA test) on ROS (%)	Random under sampling (%)	Feature selection (ANOVA test) on ROS (%)
1	LR	82.91	84.59	83.59	84.39	79	82
2	SVC	84.31	84.59	85.97	85	82	82
3	RF classifier	90.47	87.95	92.85	88	91	89
4	Decision tree classifier	85.99	85.43	88.09	87	86	88
5	KNN	68.34	77.87	73.28	83	67	79
6	ANN	88.32	88.80	94.12	87.61	92.10	90.56

Table 7. Execution time requirement (database-2)

Sr. No	Execution time	All dataset (sec)	Feature selection (ANOVA test) (sec)	Random over sampling (sec)	Feature selection (ANOVA test) on ROS (sec)	Random under sampling (sec)	Feature selection (ANOVA test) on ROS (sec)
1	In sec.	14.55	3.67	22.12	6.37	13.52	3.45

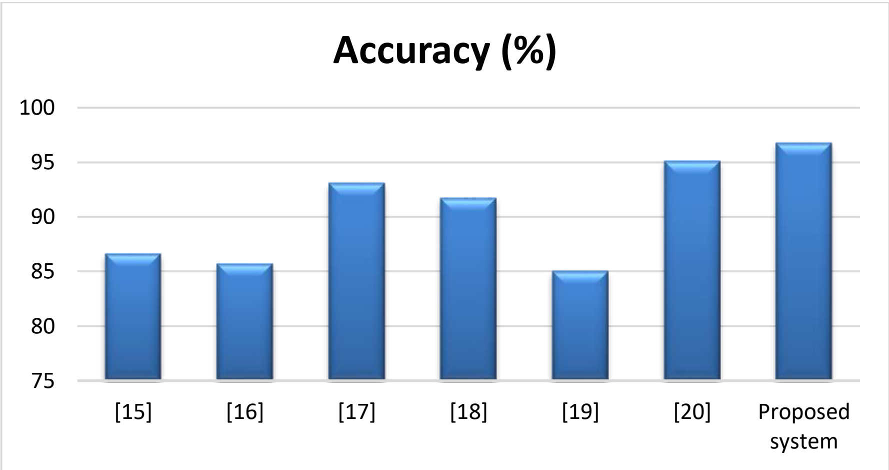

Figure 6. Comparison analysis of different method and their accuracy

In Tables 7, 8, and Figure 6, we now compaire our model with different methods and we achieved an accuracy of 96.74% for ANN systems, which is the best among all existing models. The proposed method can be used in remote areas without contemporary medical services if a doctor is available to serve.

Table 8. Comparison of proposed system with existing system

Study	Year	Dataset used	Methodology	Classifier, model	Accuracy (%)
[16]	2021	Cleveland UCI	Neural network	MLP	85.71
[17]	2022	Cleveland UCI	ML	LigntGBM	93.06
[18]		Cleveland UCI	DCNN	CNN	91.7
[19]	2022	Cleveland UCI	ML and decision tree	SVM	85
[20]	2022	Cleveland UCI	RNN, LSTM	Hybrid	95.10
Proposed system	---	Cleveland UCI	Chi-square with random undersampling	ANN	96.74

4. CONCLUSION

The authors found the best techniques for selecting the features for a hybrid decision support system by balancing random oversampling and undersampling with proper classifier selection. We achieved an accuracy of 96.74% for ANN systems, which is the best among all existing models. The proposed method can be used in remote areas without contemporary medical services if a doctor is available to serve. In the future, the performance of heart disease prediction is expected to be improved during implementation, even though most of the methods identify the heart sound precisely.

In the future, we need to focus on methods that would allow the hospital data to cover more storage space since the hospital records include more details regarding each patient. In the future, data imbalances should be cleared since they are more complex and affect the prediction process.

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